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INDOOR ENVIRONMENT DEPARTMENT

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Notice

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INDOOR ENVIRONMENT DEPARTMENT

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1. Energy Performance of Buildings

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A. Infiltration, Ventilation, Indoor Air Quality
Sponsor(s): DOE-EE
Collaborator(s): University of Alberta

Background

Using between 2-4 Quads of energy, infiltration is a major energy expense in existing envelope-dominated buildings. Much of this project is devoted to the characterization and optimization of infiltration in small buildings. Model development, instrumentation design, test methods, analysis and stock characterization are all continuing pieces of the work in this area. Understanding the impacts of infiltration and ventilation for both energy and indoor air quality is done through modeling and measurement. Combined heat and mass transport modeling (e.g. in the infiltration heat recovery project) is necessary to accurately determine energy use and potential retrofits.

In new construction, infiltration is much less and does not normally provide sufficient ventilation for acceptable indoor air quality. Accordingly this project supports ventilation standards through scientific research and also participation in consensus standards and code support. Max Sherman is chair of ASHRAE's Residential Ventilation standard (62.2P) and also serves on the non-residential standard. Data collection and analysis of air tightness of new construction is currently in progress.

Technology transfer and implementation support activities to state, federal, and international groups is a continuing effort. LBNL represents the US at Annex V of the IEA/ECBCS project, the Air Infiltration Centre. LBNL staff strongly support ASHRAE, ASTM and other consensus activities as well as assisting others in program and code development. Scientific and popular articles are also used to assist users in making use of DOE-funded research.

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At its November meeting SPC 62.2P reviewed and discussed the comments generated from the first public review of its residential ventilation standard. After extensive debate and consideration of the issues, the committee made extensive changes to the document and assigned various members to execute the committee's instructions prior to the ASHRAE Winter Meeting. The new document incorporates those changes and will be the basis of a possible vote for second public review at the ASHRAE Winter meeting. There were extensive wording and format changes to improve clarity (such as

changes to tables and equations, inclusion of a climate map and changes to the definition). There were also significant changes to the technical content, many of them highly interlinked. The sections below summarize the important aspects of these technical changes;. Additionally both a revised standard and a more detailed summary of how the committee responded to six specific comments that were repeated hundreds of times from a campaign initiated by the National Association of Home Builders was generated.

Whole-Building Ventilation: The biggest single change to this section (4) of the standard was the concurrence with commentors that houses were leakier than we gave credit for and that the total ventilation rate was higher than a minimum standard needed. The committee therefore increased the default infiltration credit and lowered the default mechanical ventilation requirement. Additional infiltration credit beyond the default could garnered using ASHRAE Standard 136.

Because the new mechanical rates were lower, the requirements on system type, backdraft testing and dehumidification were significantly reduced. The lower rates also allowed an exemption for mechanical ventilation for those houses or in those climates where space conditioning was not used more than 10% of the time.

Local Ventilation: The key changes to the local ventilation requirements were to require exhaust ventilation (to the outdoors) in circumstances where it was optional before. Specifically the standard now requires exhaust fans in bathrooms, kitchens and rooms with unvented combustion appliances. Utility rooms and toilets with windows are not required to have dedicated exhaust fans. Exceptions for air cleaning were deleted.

Combustion Issues: The single biggest change relating to combustion issues related to Carbon Monoxide alarms. In conjunction with several other changes, the committee deleted this requirement from the standard. The requirement to backdraft test combustion appliances was further limited to naturally aspirated ones inside the pressure boundary. Furthermore when large exhaust equipment had interlocked make-up air, the need to test the appliances could be avoided completely.

Filtration: The standard continues to require MERV 6 particle filtration in air handling systems. The task group and a group of industrial interests are still rectifying several conflicting comments on the specific details related to pressure drops associated with filters. Further improved wording is anticipated for the next meeting, but the changes are not expected to be large. The committee did decide to delete the informative appendix of filters as it was found to be confusing and not terribly useful by the commentors.

Air Moving Equipment: The biggest change to (section 7) was an updating of the Prescriptive Duct Sizing table to accommodate 3" ducts as sought by several

commentors. Noise limits on fans were maintained, but the specifics have been modified to account for the fact that more equipment is commonly available and for changes to the HVI rating methods.

Other Requirements: The biggest remaining change in requirements (to section 6) relates to garages. Ducting and air handlers are not allowed in garages unless they pass a duct leakage test. Furthermore, doors between a garage and the occupiable space must have door closers.

Other Informative Appendices: Informative appendices on O&M, sources, and systems were updated and errors corrected. The information contained in these appendices was found to be useful to the commentors and potential users of the document.

General and Philosophical Issues: There were multiple comments requesting that committee not do what it was charged do in its Title, Purpose and Scope (TPS) or that these sections be changed. Although there may be some areas in which more clarity would be beneficial, the committee disagreed with the interpretation of the commentors on these issues. It is not, however, the committee's responsibility to change the TPS of the standard or the policies of the Society. These issues have been forwarded to the Standards Committee for their consideration.

A rough draft of a paper on infiltration heat recovery intended for the 2001 BETEC conference was prepared. Problems with the CFD analysis have limited the amount of new simulation data available for the paper, but significant advances in the theoretical approach and derivation of the IHR effect are being documented in the draft paper.

B. Residential Envelopes and Commissioning

PIER Residential Commissioning Project
Sponsor(s): DOE, California Energy Commission (CEC)
Collaborator(s): None

Background
Currently, houses do not perform optimally or even as many codes and forecasts predict, largely because they are field assembled and there is no consistent process to identify deficiencies or to correct them. As a step toward alleviating this problem, the Public Interest Energy Research (PIER) program of the California Energy Commission (CEC) is funding our research project to lay the groundwork for a residential commissioning industry in California. The vision is that this industry will focus on providing end-use energy and non-energy performance assurances for new and existing houses.

To accomplish the goals of this 30 month-long project, which began in September 1999, scientific research methods are being used, with oversight by industry stakeholders and the CEC. These methods include field data collection, laboratory measurements, simulation, and analysis of existing and newly acquired information. We have already completed and published a literature review of existing information on commissioning. We are now midway through our study of metrics, diagnostics, and norms to ascertain what potential benefits one can realistically expect from residential commissioning. By the end of this year, we will begin to write one or more commissioning guides to allow non-experts to achieve these benefits. Project results will also be disseminated through various industry meetings and publications.

December 2000

On December 1, 2000, we hosted the third Residential Commissioning Project Advisory Committee (PAC) meeting at LBNL. At that meeting, Rick Chitwood of Chitwood Energy Management presented results from the Residential Construction Quality Assurance project, which a separate group is carrying out for the CEC. Of particular note, their attempts to use daytime interior infrared thermographic scans to quantify exterior wall framing fractions and installed insulation system area-weighted conductance were unsuccessful. As a result, there still is no practical field diagnostic to quantify envelope thermal performance. We need to conduct further research to develop such a test.

During the PAC meeting, we presented preliminary results from our Fall 2000 field and laboratory studies. Our focus was on diagnostics for duct leakage, register flow, air handler fan flow, and refrigerant charge. It is now clear that we need to develop calibration and field usage standards for measuring register and air handler flows, as well as for evaluating refrigerant charge. In addition, we presented summaries of our recent literature reviews on envelope moisture diagnostic tools and protocols and on combustion safety tests. Further development of combustion safety tests is needed to address the significant number of false-positive and false-negative results that have been obtained by others using existing tests defined in ASTM and CGSB documents.

At the PAC meeting, we also solicited input on how to proceed with the remaining work in the project: the potential value analyses and commissioning guides. That work will incorporate information from the literature that we have reviewed, from the workshop discussions that we hosted at the ACEEE conference in August 2000, and from our field and lab test results. To facilitate discussions at the PAC meeting, we presented a draft plan for the potential value analyses and a summary of the ACEEE workshop. In a concluding discussion of future directions for residential commissioning research, we summarized opportunities for using commissioning to reduce the peak energy demand of new and existing houses.

On December 6, 2000, Iain Walker and Craig Wray presented "HVAC Performance Testing: New Protocols and Techniques" at the Home Performance Strategies II Conference in San Ramon, California. As in our PAC meeting, emphasis was placed on duct leakage, register flow, air handler fan flow, and refrigerant charge diagnostics. There was substantial interest and discussion regarding our findings on register flow measurement accuracy. Our tests showed that conventional non-powered flow hoods are sometimes an order of magnitude less accurate than what many in the HVAC industry believe. One of the flow hoods that we tested is still in development stage (Digital Air). The manufacturer indicated that they are interested in pursuing further tests of their new equipment when it is ready.

Also during the Home Performance Strategies II Conference, Iain Walker and Craig Wray, together with Rob Hammon of Consol Inc. and Rick Chitwood, conducted a half-day field demonstration to building contractors of residential commissioning diagnostics. The demonstrations included how to use glazing thickness and emissivity detectors, how to conduct manual duct pressurization and automated deltaQ duct leakage tests, and how to measure supply register and return grille flows using non-powered and powered flow hoods. We also described the steps in carrying out a superheat test to evaluate refrigerant charge. Unfortunately, the weather was too cool to run the condensing unit for an actual test.

The inability to conduct the superheat test reinforced the need to develop refrigerant charge diagnostics for use during cool weather. The impact of not testing was clear from our September 2000 field tests. Two of the houses that we tested then had cooling systems installed during February 2000, when it may have been too cool to carry out superheat tests. Had the contractor been able to carry out those tests immediately after installation, they would have found the cooling systems were significantly undercharged (assuming our results were not caused by the charge leaking out after installation).

Work continued this month using CONTAM to model a residential duct system that we will construct in January 2001 as part of the CIEE/PG&E project. The object of the simulation work is to further evaluate possible sources of bias and precision errors in the deltaQ duct leakage test method. We have completed an initial model of a house and duct system. Work has begun to automatically generate input, run the simulation, and analyze the output within a Newton-Raphson solver framework. We plan to simulate 48 combinations of two envelope leakages, two supply duct leakages, two return duct leakages, and three duct leak locations (at the plenums, at the registers, or distributed throughout the system), with and without wind effects.

C. Residential Distribution and HVAC Systems

Thermal Distribution System Figures of Merit

Sponsor(s): DOE, CIEE
Collaborator(s): None

Background

Forced air thermal distribution systems in residences typically lose about 30% of the energy they consume. Because this is a large fraction of the energy consumed by the HVAC system, it is important to be able to provide good estimates of thermal distribution system efficiency. To accomplish this we are developing an ASHRAE Standard to determine the distribution system efficiency of forced air (and hydronic and electric) systems. Also, we have developed sophisticated forced air distribution system computer simulations that are being used to identify potential duct system improvements. These figures of merit are already being used by several authorities (e.g. California Energy Commission and Environmental Protection Agency).

December 2000

A major effort this month concentrated on preparing an interim report for the PG&E/CIEE project the PG&E project management team. This report included updates and summaries for all the tasks in the project, as well as the draft DeltaQ and Sizing and Comfort reports (discussed below).

A draft report on Sizing and Comfort in Residential HVAC systems was prepared this month. This report summarizes the modeling work on residential duct systems and the results of different sizing and thermostat strategies. This work showed how a good duct systems allows the capacity of residential systems to be reduced by 25% without reducing comfort. These improved systems are both more energy efficient (by about 25% to 50%) and have reduced peak demand that scales with the capacity reduction. The results of the thermostat strategy testing showed how turning cooling systems off at peak hours if the building is unoccupied can save significant amounts of energy (up to 60%), however, only good systems are able to cool a house rapidly enough that it is comfortable for occupants returning to the house in the evening.

Longevity testing of duct sealants continued this month and the results of our testing have been used to prepare a new draft of an ASTM duct leakage longevity standard. This new ASTM draft uses heating only instead of the cyclic heating and cooling in the previous draft. This use of heating only is a direct result of our longevity test results that showed how the sealants failed fastest for heating only and the same sealants failed for cyclic and heating only testing. There has also been support for this simplified test procedure from the ASTM E06.41 subcommittee who will be voting on this draft standard in the new year.

This month we stepped up the efforts on planning and constructing our new duct system evaluation laboratory. This laboratory is being developed to test flows and pressure drops in a "typical" full size duct system. The planning for this facility

includes determining the materials for constructing the facility and developing new measurement techniques for determining the system flows and operating pressures. This work is complicated by the fact that standard duct airflow measurements require many duct diameters of uninterrupted flow upstream of measurement locations and this is not possible in the "real" duct system we are building. A promising development is to use simple propeller devices placed in the duct to measure the flows. These propeller devices will be constructed and calibrated as part of the experimental design and used in conjunction with commercially available nozzle flow meters to determine the flows in the duct system. Once completed, we plan to use this apparatus to measure the pressure losses associate with duct fittings not found in existing design manuals and also to evaluate register air flow measurement devices.

We continued to provide technical support the CEC regarding proposed changes to Building and Equipment Energy Efficiency Standards under the California AB970 legislation. This work has been carried out in collaboration with other LBNL/DOE staff, CEC staff and our research project sponsors (e.g., PG&E). In December, the CEC drafted proposed changes to the State Energy Code for residences to that includes requirements championed directly by LBNL: sealing of forced air ducts and the use of TXV controllers on air-conditioning systems. Other changes included increased minimum heating and cooling equipment efficiency, improved windows and the use of radiant barriers. We are collaborating with other LBNL and DOE staff on pursuing higher equipment standards (Title 20). We have had key meetings with DOE staff regarding the use of higher minimum equipment efficiency specifications, TXV controls and energy efficient air handler fans.

Distribution System Measurements
Sponsor(s): CIEE, DOE
Collaborator(s): Richard Heath & Associates, CA State University-Chico

Background
Estimates of residential HVAC system performance require measurements of several characteristic parameters. We are writing standard test procedures (through ASHRAE and ASTM) for the building industry to use. This includes development of new test procedures (e.g., the DeltaQ test for residential duct leakage) and evaluation and improvement of existing procedures. Both field and laboratory testing are being used to identify key aspects of distribution system performance so that these systems can be improved in both new construction and retrofits of existing buildings. The field measurements give a baseline for estimating peak demand and energy consumption. The laboratory measurements allow development of test procedures and equipment under controlled conditions.

December

A draft report on the DeltaQ duct leakage test method was completed this month. The report includes a technical derivation of the test method, test protocols, summaries of all the field tests to date and uncertainty analyses.

We are continuing work on development of simulation techniques of DeltaQ tests, which have concentrated on using CONTAM in Monte-Carlo type simulations. This will allow us to investigate the effects of changing weather conditions during tests as well as exercising other input parameters.

We gave a presentation on "HVAC Performance Testing" at the Affordable Comfort meeting in San Ramon. This presentation concentrated on our evaluation of simple diagnostic techniques suitable for use by HVAC contractors. A key issue raised by our CEC Commissioning Project that was discussed in this presentation is the poor performance of commercially available flow hoods for measuring residential register flows. The audience participants for this presentation were extremely concerned about this issue and is it clear that some sort of industry standard test method needs to be developed.

We gave a field training session on "Diagnostic testing of residential HVAC systems" at the Affordable Comfort meeting in San Ramon. At this field training session we spent a morning in a house demonstrating the advanced diagnostic techniques we use on residential HVAC systems for measuring air flows, thermal conditions and refrigerant system performance.

The coil fouling experiments are continuing. Experiments have been completed for 2.5 and 5 micron particles for the isothermal coil. Preliminary testing has begun on the generation of smaller (1 μm) and larger (8 μm) particles. A report has been started that will form the basis for a paper to be submitted to the United Engineering Foundation Conference on Heat Exchanger Fouling. We have obtained some pictures from a scanning electron microscope of accumulated matter on a coil. They do not suffer from the depth of field issues we had with previous efforts using an optical microscope, but they are in black and white.

Innovative Duct Technology
Sponsor(s): DOE
Collaborator(s): PEG

Background
This DOE STTR is developing a new forced air duct system that uses simple snap together fittings that eliminate duct leakage and many duct system installation problems. Our contribution to this work is to perform field and laboratory testing of the new duct assemblies and to provide commentary and assistance in development of the final design.

December 2000
We are waiting for PEG to send samples to be tested.

D. Commercial Distribution and HVAC Systems

Performance Characterization of Large Commercial Buildings
Sponsor(s): DOE-EE
Collaborator(s): None

Background
The project goal is to further advance the knowledge about system performance of thermal distribution systems in large commercial buildings.

December 2000
We finished the draft final report on the field studies of duct systems in two large commercial buildings. Further review comments from co-authors are being incorporated into the report. Some of the final results are:
a) Large variations of duct leakage areas, operating pressures in large commercial system exist. Flow pressures in main supply-ducts and some VAV branches also exhibited significant changes over time in the VAV systems.
b) Energy use of system's main-fans tended to decrease with the decrease in main-fans' airflow. The variable-speed-driven supply-fan showed more significant power variations with the change of air flow rate than inlet-vane-controlled supply fan did. VAV systems did provide energy and peak demand savings by means of controlling airflow based on zonal cooling loads.
c) Instant temperature effectiveness correlates well with supply airflow in branch ducts, i.e., duct sections downstream of VAV terminals. Specifically, temperature effectiveness on branch-duct level decreased with the decrease of supply airflow.
d) Magnitudes of supply-air temperature rises tended to increase with duct lengths in large duct systems in general, probably due to increasing heat conduction along supply-duct walls.
e) The existence of heating coils and/or induction units attached to the VAV terminals adds more complexities in our monitoring and analysis.
f) While energy-savings potential of fan operation were great, the energy efficiency of duct systems associated with the use of VAV systems were systematically undermined due to the changes in airflow, and thermal losses induced by fan-induction and imperfect thermal system controls.

Development and Testing of Aerosol Sealing Technologies
Sponsor(s): DOE-EE
Collaborator(s): None

Background
This project is developing and evaluating aerosol-based sealing techniques that could be used in large duct systems.

December 2000
We continued to analyze the data obtained during the field testing of aerosol sealing for a large duct system. Our field experiment and analysis shows that the average sealing rates for two branches using compact injectors were 138 cm2/hr and 142 cm2/hr, respectively. They are much higher than the sealing rate (16 cm2/hr) for the main trunk using an aerosol injector. The preliminary explanation was that there might be some problem of sizes of particles generated by the injector nozzle. The experiment also showed that we could continuously use compact injectors even when the static pressure in branch-ducts becomes higher than the pressure in the main trunk.

OUTSIDE CONTACTS
Craig Wray continued to participate in conference calls on how the LEED-R Green Building Rating System that is now under development can incorporate residential commissioning.

Iain Walker and Craig Wray attended the Home Performance Strategies II Conference in San Ramon, CA during early December.

Iain Walker and Craig Wray gave a presentation on "HVAC Performance Testing" at the Affordable Comfort meeting in San Ramon.

Iain Walker and Craig Wray gave a training session on "Diagnostic testing of residential HVAC systems" at the Affordable Comfort meeting in San Ramon.

M. Modera appeared in a Sacramento TV show talking about the aerosol sealing technology.

INDOOR ENVIRONMENT DEPARTMENT

2. Ventilation and IAQ Control Technologies

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A. Ventilation Measurement Methods

Measuring Outside Air Flow in AHUs
Sponsor(s): DOE-EE
Collaborator(s): none

Background
Current ventilation data indicate that there are wide variations in ventilation rates among buildings. In many buildings, minimum ventilation rates are well below or above the rates in applicable standards. These data and our research experience demonstrate that the common methods of measuring and controlling the rate of outside air supply by air handlers are often inadequate. The consequence is poor air quality in some buildings and excessive ventilation rates in other buildings. Starting in the middle of FY 2000, we initiated a new research effort on methods of monitoring and controlling rates of outside air supply by air handling systems. The work plan is broken into five categories:

- Communication with industry (ongoing throughout the project)
- Literature/hardware review and Common Practice Survey
- Controlled rooftop (or laboratory) experimental evaluation of technologies
- Field studies (small effort before and larger effort after controlled experiments)
- Work with a professional organization to develop performance testing protocols

December 2000
There was no work on this task during December.

B. VOC Sources, Emissions, and Controls

Modeling Emissions of VOCs from Indoor Materials
Sponsor(s): DOE-EE
Collaborator(s): Virginia Tech

Background
Al Hodgson is working in collaboration with professor John Little and graduate students Steve Cox and Deept Kumar of Virginia Tech (VT), Blacksburg, VA to produce mechanistic models that describe the emissions of volatile organic compounds (VOCs) from various solid materials used in buildings. The primary objectives of this research

are to better understand and to be able to predict the impact of VOC sources and sinks in the indoor environment. An ancillary goal is to create a less-expensive and superior alternative to emissions testing in environmental chambers for estimating VOC emission rates from building materials. This effort has recently resulted in the development and validation of a physical model for predicting the rate at which VOCs are emitted from vinyl flooring, an exemplary solid-phase material. The key model parameters are the initial concentration of a VOC in the material phase, the VOC material/air partition coefficient and the VOC material-phase diffusion coefficient. These parameters are independently measured using novel methods developed as part of this project. The research collaboration is now attempting to extend the physical model to predict VOC emissions for simple bi-layered materials.

December 2000
Revisions to the manuscript, "Predicting the Emission Rate of Volatile Organic Compounds from Vinyl Flooring," were completed. This manuscript will be sent out for internal review in January.

Impacts of Ventilation Rate on VOC Concentrations and Emission Rates
Sponsor(s): DOE-EE
Collaborator(s): U.C. Berkeley, Center for the Built Environment

Background
A ventilation-rate intervention study (section 3A) is being conducted to quantify the relationships of worker performance in a call center with ventilation rate and air temperature. The three-month study period was concluded in October. The building's air handling systems were operated at three constant outside-air supply rates. The minimum rate corresponded to applicable code requirements. Ventilation rates were periodically changed over 12 weeks. The schedule incorporated both weekly and daily adjustments of the outside air damper settings. Building temperatures, relative humidities, CO_2 concentrations, and airflow rates in the air handling systems were monitored and recorded. The research team is using the opportunity provided by this intervention study to quantify the effects of building ventilation rate on the concentrations and source strengths of VOCs, including formaldehyde. Air samples for VOCs were collected from outdoor air and the four building air returns on a single mid-week day during seven weeks. The air samples were qualitatively analyzed to identify the predominant compounds present in the building. A suite of 50 compounds was quantitatively analyzed. Measured airflow rates are being used to calculate VOC emission rates for the four air handler zones.

December 2000
Analysis of the VOC, airflow rate, CO_2 concentration and building occupancy data continued. Overall plans are being developed for a technical paper based on these data.

Comfort and Health-Based Guidelines for Indoor Concentrations and Material Emissions of VOCs
Sponsor(s): DOE-EE
Collaborator(s): Building Ecology Research Group, Health Effects Institute

Background
The overall goal of this project is to develop a methodology for establishing comfort and health-based guidelines for indoor concentrations and material emissions of VOCs. Hal Levin of the Building Ecology Research Group, Santa Cruz, CA and J. Ten Brinke of the Health Effects Institute, Cambridge, MA are collaborating with A. Hodgson on this effort. A database has been developed that contains approximately 90 individual VOCs spanning a broad range of volatility and chemical functionality. Most of these compounds have been detected in North American houses and office buildings. Available data for the 90 compounds on occupational inhalation exposure guidelines, sensory irritation measured by mouse bioassay, odor thresholds, and chronic reference exposure levels established by the State of California have been summarized from the literature and incorporated into the database. A methodology for evaluating the potential for a compound to elicit a comfort or health-based response among building occupants is currently being evaluated.

December 2000
Additional recent literature on sensory irritancy and quantitative structure activity relationships was obtained and reviewed.

Joint Research and Demo Project on Energy Efficient and Healthy Homes
Sponsor(s): DOE-EE
Collaborator(s): Florida Solar Energy Center

Background
A primary objective of this research is to determine the sources and entry pathways of the most abundant and persistent VOCs in new houses, including houses with energy-efficient features. A. Hodgson, in collaboration with Subrato Chandra and David Beal of the Florida Solar Energy Center (FSEC), Cocoa, FL, is currently conducting a field and laboratory study to identify and quantify the sources of terpene hydrocarbons, formaldehyde, other aldehydes and carboxylic acids in a new manufactured house. The house is located in Florida and is used daily as a sales model. The manufacturer supplied a detailed list of all of the materials used in construction of the house. Specimens of the major materials were obtained from the production facility. Laboratory chamber tests were conducted with these materials to measure the emission rates of the target VOCs. These emission rates were used with the material quantities to estimate whole-house emission rates. The predicted emission rates were compared to emission rates calculated from the measured ventilation rates and the concentrations of

VOCs in the house approximately four months after its completion. For 11 of 14 predominant compounds, the predicted concentrations agreed within a factor of two.

December 2000
There was no activity on this task in December.

C. Ventilation and Indoor Air Quality Studies

Assessment of Particle Control Technologies
Sponsor(s): DOE-EE
Collaborator(s): Helsinki University of Technology

Background
The objectives of this effort are to quantify the reductions in indoor concentrations of particles, from various sources, that result when a variety of air cleaning measures are employed, and to characterize the associated energy costs and total costs. This work is based on analyses of existing data and modeling. The sources of particles considered are outdoor air (fine mode), dust mites, cats, environmental tobacco smoke, and droplet nuclei from coughs and sneezes. The particle air cleaning options include filtration, with various filter efficiencies, and electronic air cleaning. We are evaluating air-cleaning equipment installed within HVAC systems and stand-alone devices.

December 2000
Writing of the first draft of the paper based on this work started in December. Considerable effort will be required to concisely summarize the large number of model predictions.

Task Ventilation Optimization
Sponsor(s): DOE-EE
Collaborator(s): none

Background
In prior years, we have investigated the ability of several task ventilation systems to provide better ventilation, and reduced pollutant levels, at the breathing zone, relative to conventional ventilation systems with well-mixed indoor air. The results of the most recent set of experiments were quite promising. All of the commercially-available task ventilation systems have been designed to provide local control of thermal comfort. Improved ventilation at the breathing zone has been an incidental feature of these systems. Starting in the second half of FY2000, we initiated experiments and modeling to optimize ventilation performance. Rather than evaluate commercial products that have not been optimized for ventilation performance, we will design and evaluate new technologies for supplying air near the occupant. As of the end of FY2000, an initial set

of parametric studies had been completed to provide qualitative visual images of the airflow patterns between the task ventilation system's air outlet and the breathing zone of a heated mannequin. We also started developing the software for computation fluid dynamics (CFD) modeling of these systems. A post doctoral fellow, Seung Min Lee, started working on this effort during September 2000.

December 2000
Preparations for experiments continued. The new mannequin was wrapped with a resistive wire to enable control of the heat release from eight body segments. The controls for the chambers HVAC system were checked. Air flow meters for the task ventilation air supply were calibrated. Finally, a multipoint sampling system for tracer gas measurements with the mass spectrometer was assembled.

D. Indoor Environmental Quality and Energy Efficiency in Relocatable Classrooms

Improving IAQ and Saving Energy in Relocatable Classrooms
Sponsor(s): California Energy Commission
Collaborator(s): Davis Energy Group, Pacific Gas and Electric Company

Background
In this study, Element 6 of the California Energy Commission (CEC) funded High Performance Commercial Buildings Systems Program, we will investigate and demonstrate how the application of building science and ventilation engineering can lead to simultaneous building energy savings and indoor environmental quality performance improvements. This project focuses on developing and testing a concept for high-performance relocatable classrooms (RCs). RCs, otherwise known as "School Portables," or "Modular Classrooms," are very common in California. RCs provide school districts with quick and convenient means of adding or replacing classrooms. RCs can be moved around, reducing unnecessary classroom construction. Currently the State of California mandates that at least 20% of new classrooms be RCs.

In this project we will evaluate the benefits of a novel building ventilation system and also of selecting construction materials that emit fewer indoor pollutants. We will construct and study three or four RCs sited in California school districts. One project will test a high-performance ventilation and air conditioning system, the Indirect-Direct Evaporative Cooler (IDEC), suitable for warm dry climate zones of California. In these climates, IDEC offers potential cooling energy savings of about 70% compared to the standard (10 SEER) air conditioner used in RCs. In addition to energy savings the IEDC provides a continuous flow of outside air which will improve the indoor air quality of the RCs. A second project will focus on identifying RC materials that are VOC sources through chamber measurements in RCs. Two RCs tested in the field will be constructed using materials selected for lower VOC emissions. The project will also include an effort to develop, test, and refine computer models of RC energy performance in California. Data from the field study will be used to validate the computer simulations

and upgrade inputs to the model. Energy and cost-benefit projections will be made for different California climate zones.

December 2000

Progress was made in all planned activities. Three Northern California RC manufacturers were toured by IED staff and all three expressed desire to become participants in the CEC project. School district facilities managers in the San Joaquin Valley were contacted by mail and several were receptive to becoming involved in the project. Site visits to school districts were scheduled for January, 2001. Energy modeling efforts continued, an IDEC sizing spreadsheet for cooling requirements and thermal comfort was developed by DEG. The effort of constructing DOE2 inputs for initial energy simulations was started. General specifications for study RC construction and measurement systems for the field study were developed. Engineering calculations for development of the test HVAC heating system design were made, necessitating the re-thinking of using radiant electric heating system as the companion to the IDEC.

E. Airflow and Pollutant Dynamics in Buildings

Particle Deposition to Indoor Surfaces
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley, Dept. of Civil and Environmental Engineering

Background
Inhalation exposure to airborne particles can have adverse health effects. One fate for particles in indoors is deposition onto surfaces. Clearly, this process alters the likelihood of human exposure, since a deposited particle cannot be inhaled unless re-suspended. Knowledge of the rates of particle deposition onto indoor surfaces and the factors governing those rates is therefore important.

December 2000
A series of new experiments was conducted with 5 μm particles to measure particle deposition in the half-scale aluminum chamber (1.3 m cube). There is a significant disagreement between the existing theory and experimental findings on particle deposition to vertical surfaces. We explored one hypothesis, that electrostatic effects caused enhanced deposition of coarse particles onto vertical surfaces. The issue was explored experimentally and through modeling. Conductive materials (thin copper and stainless steel plates) and non-conductive plane smooth glass were fixed on the vertical walls inside the test chamber. For the conductive materials with the direct contact on the grounded chamber, image forces between the plate and the charged particles. For the glass surfaces, only a field force would be present. A portable electrical field meter was used to measure the sample surfaces in situ. The estimated electric field strength was on the order of 100-1000 V/m.

Mathematical models for the image and field force on particle deposition have been developed. Preliminary indications are that the electrostatic effect will not account for the discrepancy between model and measurement. Our current plan is to write up the experimental results for publication; these appear to be highly robust. Progress in this area will slow with the departure of Alvin CK Lai (a post-doctoral researcher) who has accepted a faculty position at Nanyang Technical University in Singapore, effective January 2001.

Particle Deposition in Ductwork
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering

Background
The effort under this part of the project is aimed at developing a computational predictive ability for dispersion of gases and aerosols in large indoor spaces. Such a predictive capability will allow development of exit strategies, as well as containment strategies for an unexpected pollutant release in an indoor large space. We are also interested in obtaining an improved understanding of pollutant dispersion in large Indoor spaces to reduce occupant exposures under a variety of scenarios.

December 2000
M. Sippola has purchased materials for modification of the experimental duct run to a re-circulating system from a single pass system. A broken piece on the Vibrating Orifice Aerosol Generator had slowed experimental progress, this generator has now been repaired and is ready to use. Also, samples of ventilation ducts from two San Francisco office buildings have been acquired to measure the surface roughness of some real ventilation ducts.

A draft of a document (potentially an LBNL Report) covering particles in HVAC systems, turbulence in HVAC ducts, and particle deposition modeling in HVAC systems has been partially written.

Particle Penetration through Building Cracks
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering

Background
The goal of the particle penetration through building cracks investigation is to explore the extent to which particles in infiltrating air remain airborn as the air passes through the building envelope. The work started with modeling, and now includes experiments to validate the predictions. We have finished the idealized crack experiments and will embark on realistic building cracks soon. These results are expected to help us gain

insight on the protection of building shell might offer, especially for air leakage dominated buildings.

December 2000

D. Liu has focused on preparation for field measurements of particle penetration factors in a single-family residence in Fresno. We will employ particle instruments such as the APS (aerodynamic particle sizer) and optical particle counters (LAS-X) indoors and outdoors. A fan system will be used to pressurize and depressurize the house and the indoor and outdoor particle concentrations will be measured. Several oscillating fans will be used to enhancing the mixing in the house. The aim is to determine the particle penetration factor and its relationship to overall air exchange rate.

Multizone Simulation and Model Development

Sponsor(s): DOE-CBNP, LLNL

Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering, Dept. of Architecture

Background

This task seeks to develop and implement models for pollutant transport in buildings. This includes coupling the COMIS multizone airflow program with the MIAQ4 aerosol dynamics model. The model development effort aims to improve our capabilities for predicting gas and aerosol transport in heterogeneous multi-room indoor environments. The models have two major applications: (1) as tools used directly to predict airflow and pollutant transport in buildings; and (2) as testbeds to check our understanding of the physical processes that explain experimental data on pollutant transport.

December 2000

L. Mora and D. Curtil jointly presented a seminar on numerical issues with solving zonal model problems using SPARK. First, they showed that the problem description strategy has a strong impact on the numerical stability of the solution algorithm. Second, their tests demonstrated that the new features of the SPARK solver improved its robustness.

L. Mora developed an analytical approach to estimate the mixing time of a point-source pollutant release in an occupied room with weak air flows.

D. Lorenzetti finished a report on the long-term usefulness of the COMIS multizone airflow program, and sent it to reviewers.

EMPA has not yet reached a decision regarding licensing of COMIS v. 3.1.

A brochure and CD-ROM, "Hybrid Ventilation in New and Retrofitted Office and Educational Buildings," is now available. These materials represent the first publications by the International Energy Agency's Annex 35. The CD contains a "State of the Art" report on hybrid ventilation, as well as case studies and individual papers collected by the Annex. Most of the funding for U.S. participation in this effort came from DOE-EE.

Prototypical Building Characterization
Sponsor(s): DOE-CBNP
Collaborator(s): None

Background
This project's goal is to develop building management strategies to reduce occupant exposures to an unexpected release of a toxic aerosol or gas. The release could be indoors or in the building vicinity. Our approach is to develop prototypical model buildings that represent the general building stock and to use them to simulate hypothetical pollutant releases. The concentration predictions will help us understand how pollutants are expected to distribute in a building and how event-specific uncertainties might affect the generalizations. Rules-of-thumb response strategies will be developed based on the model predictions. We are currently developing response strategies for commercial office buildings.

December 2000
We worked on completing a journal manuscript that describes our approach and the analysis tools that we developed, and describe several illustrative results. That manuscript went through internal review and was determined to be too much material for fitting into a single paper. So, we have revising the original manuscript to have the first part focus only on the framework and tools.

We also completed an internal draft of a guidance brochure for first responders to a CB agent release in or near a commercial building. The draft will be internally reviewed next quarter before broader circulation for comments.

Air Flow and Pollutant Dispersion in a Large Room
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): None

Background
We are using a combination of computational fluid dynamics (CFD) modeling and experimental work to advance CFD models for use in buildings and to help us to develop a simpler "lumped parameter" model for air flow and pollutant dispersion in a single, large room, *e.g.*, an auditorium, to incorporate into COMIS. This work also involves a collaboration with scientists in France who are developing CFD models.

December 2000

E. Finlayson completed the definition of multiple releases in the Atrium facility model. These releases were incorporated into the mesh and preliminary pollutant dispersion calculations were made. Examination of these results indicate that we will have to use the NERSC facility to obtain results in an acceptable time frame. This work will eventually be incorporated into a paper exploring the mixing time concept in the Atrium facility.

M. Fischer received reviewers comments on the manuscript describing the Tinbox experiments, revised the manuscript, and returned it to the editor. Fischer also supervised analysis of data collected from experiments in the Tinbox during summer, 2000.

P. Price is leading the "first responders" group's efforts. He completed a draft of instructional materials for "first responders" to an indoor toxic release. These materials include illustrations of different kinds of ventilation systems, and how these systems carry contaminant through the building. The cases of HVAC on and HVAC off are illustrated separately, and implications of indoor/outdoor temperature differences are shown. The draft has been distributed for comment, and will be revised before the end of January.

Ashok Gadgil visited University of La Rochelle in December as a member of the doctoral thesis examination jury for Ms. Anne Sergent. She had conducted research in large eddy simulation of natrual convection at high Ra numbers in tall two-dimensional enclosures. During the visit, Ashok Gadgil met with several colleagues and had useful scientific discussions.

We made progress on the processing of paperwork for Dr. Marc Abadie from U. La Rochelle, who will arrive in early 2001 for a 16 month research assignment in lieu of his military service.

Christian Lobscheid continued to make progress with learning the software StarCD which he will begin to use for his master's thesis research in early 2001.

M. Sohn has accepted a position as Scientist in the Airflow and Pollutant Transport Group of the Indoor Environment Department. He will be dividing his time between the indoor airflow and pollutant transport model work that he is doing for the Prototypical Building Characterization research with statistical uncertainty analysis work that we is conducting with T. McKone in the Exposure and Risk Assessment Group.

F. Service to Professional and Governmental Organizations

ASHRAE
Sponsor(s): DOE-EE
Collaborator(s): none

Background
Bill Fisk serves on ASHRAE's Environmental Health Committee (EHC's), as chairman of the EHC's Research Subcommittee, and on ASHRAE's IAQ'2001 Organizing Committee.

December 2000
Another set of abstracts for the ASHRAE IAQ 2001 meeting was reviewed. Also, research plans for the Environmental Health Committee were developed and summarized in a memorandum for distribution to ASHRAE Technical Committees (TCs) and Standard Project Committees (SPCs). The new plans focus on coordination of environmental health research and providing assistance to SPCs and TCs.

Indoor Air 2002 Organizing Committee
Sponsor(s): DOE-EE, AIHA, and many other sponsors
Collaborator(s): U.C. Berkeley, California Department of Health Services

Background
The Indoor Air 'xx conference, held every three years, is the largest and most prestigious international indoor air quality conference. Hal Levin, Bill Nazaroff, Bill Fisk, Rich Sextro, and non-LBNL staff are serving on the organizing committee for the Indoor Air 2002 organizing committee, with Hal Levin serving as the Conference President. DOE contributed $30K during FY2000 to the organization of this conference. Support from a large number of sponsors is anticipated.

December 2000
The brochure for sponsors and exhibitors was completed and printed and distribution was initiated. The conference database of potential attendees was expanded. Negotiations progressed on an agreement with the International Society of Indoor Air Quality and Climate. Work started on applications for conference support grants from EPA and NIOSH.

OUTSIDE CONTACTS

December 2000
Bill Fisk met with Mukesh Khattar of EPRI to discuss the scope and participants of a IAQ research planning effort for the California Energy Commission.

INDOOR ENVIRONMENT DEPARTMENT

3. Healthy Buildings and Productivity Studies

W.J. Fisk
510-486-5910

A. Experimental Healthy Buildings and Productivity Research

Healthy Buildings Intervention Study
Sponsor(s): DOE-EE, NIOSH, EPA
Collaborator(s): NIOSH

Background
LBNL and NIOSH have conducted a blinded-controlled intervention study in an office building to evaluate the effects of enhanced particle filtration systems, improved surface cleaning, and air temperatures on health symptoms. The filtration intervention involved switching on a weekly basis between typical and high efficiency filters on two floors of an office building. On Thursday or Friday afternoon of each week, occupants reported their health symptom intensities for the current day. Extensive environmental measurements were performed throughout the study. After the seven-week filtration intervention study, a surface cleaning intervention, consisting of special intensive vacuuming of floors and chairs, was performed on one floor with the occupants of the second floor serving as the control group. A third "natural experiment" occurred throughout the study due to natural temporal variations in indoor air temperatures. A short paper on the filtration intervention was published in FY2000.

December 2000
Mark Mendell continued to finalize the full-length journal paper describing the health-related findings of the particle intervention and time varying indoor air temperatures. The paper was revised to address all comments of the internal reviewers and then provided to a set of external reviewers. We expect to receive the external review comments in early January.

Ventilation Rate Intervention Study
Sponsor(s): DOE-EE
Collaborator(s): Center for the Built Environment

Background
In this study, we are quantifying the relationships of worker performance in a call center with building ventilation rate and air temperature. Worker performance is being determined from the automatically-recorded telephone call data at three relatively constant outside-air ventilation rates, and also with the economizer system operating. The minimum ventilation rate corresponds to applicable code requirements. Periods of

steady ventilation rates range from one week to one day. Indoor air temperatures and building occupancy fluctuate naturally. Temperatures, humidifies, carbon dioxide concentrations, and VOC concentrations are being monitored.

December 2000
Entry of productivity data continued. In addition, work started on the statistical analyses of the data from the productivity intervention study. LBNL and UC Berkeley staff met with a bio-statistician to discuss the preferred method of analyzing the data. A new statistical approach is under consideration.

B. Literature Reviews and Assessments

Association of HVAC Type and Features with SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): Helsinki University of Technology

Background
Cross-sectional studies from around the world have investigated the relationship of HVAC system type in commercial buildings with occupant health symptoms. LBNL and the Helsinki University of Technology are collaborating on a critical review of the literature. This document will summarize the findings of studies that satisfy study quality criteria and review the evidence supporting or refuting the hypothesized explanations for the observed associations.

December 2000
Comments were received from one of the reviewers of the draft paper and the paper is being modified to address these comments. The second reviewer did not provide comments until the middle of January. We anticipate submitting the paper to a journal in February.

Health and Productivity Reviews
Sponsor(s): DOE-EE
Collaborator(s): None

Background
In this area of work, critical reviews are performed to assess the opportunities for health and economic gains from improvements in indoor environmental quality.

December 2000
Publication of the handbook chapter by McGraw Hill was not completed in late December as scheduled. However, our health and productivity article was published in Annual Review of Energy and the Environment.
The citation follows:

Fisk, W.J. (2000) Health and productivity gains from better indoor environments and their relationship with building energy efficiency. *Annual Review of Energy and the Environment* 25(1):1-30.

IAQ and Health in Schools
Sponsor(s): DOE-EE
Collaborator(s): University of Minnesota

Background
In 1999, the IED, working with Bill Angel at the University on Minnesota, completed a report on a broad review of IAQ and associated health problems in schools. A conference article based on this review was presented in FY1999. The FY2001 plans are to complete and submit a journal article based on this work.

December 2000
At the start of January, we received the results of the journal's review of our paper on IAQ and associated health problems in schools. The paper was accepted contingent on some modifications which include a substantial decrease in length.

C. Analyses of Data from the EPA BASE Study

VOCs and SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): EPA developed the database for these analyses

Background
EPA has collected a large set of data from office buildings, including building characteristics, air pollutant concentrations, and SBS symptom prevalences. We have used statistical models to analyze data from the first set of buildings and learn about the associations of volatile organic compounds with symptoms. The analysis will now be extended, using the data from all 100 buildings.

December 2000
During December we continued to conduct data cleaning and processing activities with the 100 building BASE dataset. The canister and multisorbent VOC data and CO_2 data processing was completed.

Carbon Dioxide and SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): U.S. EPA

Background

For this task, we are using multivariate statistical models to analyze data from the EPA BASE study to investigate the association of indoor carbon dioxide concentrations with SBS symptom prevalences.

December 2000

During December we continued to conduct data cleaning and processing activities with the 100 building BASE dataset. The VOC and CO_2 dataset processing was completed.

The following paper was also published in the journal Indoor Air.

> Apte, M.G., Fisk, W.J., and Daisey, J.M. (2000) Associations between indoor CO_2 concentrations and sick building syndrome symptoms in US office workers: an analysis of the 1994-1996 BASE Study data. *Indoor Air* 10(4): 246-257

D. Service To Professional And Governmental Organizations

National Occupational Research Agenda

Sponsor(s): DOE-EE supports time of LBNL staff serving on the National Occupational research Agenda Indoor Environment Team. The objectives of this interdisciplinary team established by NIOSH are to develop a priority research agenda related to IAQ and health in non-industrial occupational buildings, and to foster partnerships and collaborations as needed to implement the research agenda.

Collaborator(s): Broad representation on Committee from government, universities, labor

Background

Bill Fisk is participating in the activities of the National Occupational Research Agenda (NORA) Indoor Environment Team. This multi-disciplinary team is developing a paper on the highest priority research needs related to IAQ and health in non-industrial occupational environments.

December 2000

The NORA IEQ Team document is facing a delay from the NIOSH Office of the Director because of concerns about the policy content. This issue will be discussed in the next team telephone conference call.

California IAQ Interagency Working Group

Sponsor(s): DOE-EE supports the participation of LBNL staff in these meetings

Collaborator(s): Broad representation from the sponsors and performers of IAQ research in California

Background

The California Interagency Working Group (CIAW) meets quarterly to maintain communication on IAQ activities in California. Mike Apte serves as LBNL's representative.

December 2000
A working group meeting was held in December. Mark Mendell attended the meeting and made a presentation on the relationship of building HCAC with health.

OUTSIDE CONTACTS

December 2000
Bill Fisk was contacted by the chairs committees developing environmental and energy credits for the Green Buildings Council Commercial Interiors effort. Bill provided extensive comments on the proposed credits.

Mark Mendell worked with the editor of the popular IEQ Strategies Newsletter to prepare a summary of our previous paper on the relationship of occupant health with ventilation rates and carbon dioxide concentrations.

INDOOR ENVIRONMENT DEPARTMENT

4. EXPOSURE AND RISK RESEARCH

T.E. McKone, W.J. Fisk, A.T. Hodgson, R.G. Sextro
486-6163

A. Environmental Tobacco Smoke Research

Further Characterization of Environmental Tobacco Smoke
Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): None

Background
In this project, led by Rich Sextro, laboratory and field research is being conducted to assess the usefulness of particle-bound components of ETS as tracers for exposure assessment studies.

December 2000
We presented a summary of our recent work, including the results of the three-home pilot field study, at the Annual Investigators Meeting of the TRDRP in San Diego. In the laboratory we validated our new analytical method for simultaneous determination of scopoletin, UVPM and FPM in extracts of ETS particles. Work continued on the project final report and a proposal to measure ETS tracer behavior in 20 residences.

Vapor-Phase Organics in Environmental Tobacco Smoke
Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): U.C. Berkeley Department of Environmental Engineering

Background
Brett Singer and Al Hodgson are working on this project with assistance from several undergraduate students in the U.C. Berkeley Environmental Engineering Department. The project focuses on quantifying human exposure to vapor-phase organic compounds in ETS under a range of realistic smoking patterns and ventilation rates. Special attention is being paid to sorption processes that can have a large impact on airborne concentrations of semi-volatile organic compounds (SVOCs; *e.g.*, nicotine) both during and long after active smoking periods.

December 2000
In December, we continued to analyze the data from our experiments in the simulated residential environment chamber and the stainless steel chamber. We also started to prepare an article for journal publication that presents the results of our experiments in which vapor-phase ETS emission factors were measured under varying ventilation rates and smoking patterns.

B. Performance of Smoking Rooms

Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): California Department of Health Services

Background

The IED and the California Department of Health Services (CDHS) are studying the performance of smoking rooms. Laboratory studies will assess the rate of ETS leakage from a smoking room to the adjoining space as a function of smoking room physical characteristics, door usage, and temperature and pressure differences. A mathematical model of smoking room performance will be developed and model predictions will be compared with measured data. A final phase of the project will assess the accuracy of the model in predicting the performance of smoking rooms located in a small number of office buildings.

December 2000

Measurements of environmental tobacco smoke (ETS) leakage from a smoking room continued. Two experiments were completed in December. Both were run with improved temperature controls, as well as a modified ventilation system that compensated for the high-volume sampling pumps. In the first test, the smoking room and the adjoining, non-smoking room were operated at the same room pressure. In the second, the smoking room was at an elevated pressure of 5 Pa. The smoking room was 30% less effective at exhausting the ETS when it had an elevated pressure. The concentration of ETS in the non-smoking room was 5 times higher when the pressure difference existed. Flow under the closed smoking room door was a more significant mechanism for ETS leakage than the bursts that occurred when the door opened. These results are consistent with our previous, independent tests of each mechanism.

In addition, refinements were made to the HPLC method for measuring Scopoletin, a particle-phase ETS component which can be extracted from the filter samples. Filters from two experiments were extracted, a standard curve for Scopoletin was established, and the extractions were analyzed. Nicotine samples were brought to the Department of Health Services for analysis.

C. The California Exposure Modeling Research Center

A Multi-Domain Framework for Integrating Models and Measurements of Multimedia Environmental Contaminants
Sponsor(s): U.S. EPA National Exposure Research Laboratory
Collaborator(s): U.C. Berkeley, Stanford University

Background

Tom McKone, Deborah Bennett, Neil Klepeis, Randy Maddalena, William Riley, and Agnes Bodnar are working on this project at LBNL; Wayne Ott and Paul Switzer are working on this project at Stanford University; and William Nazaroff, Katharine Hammond, and Michael Tarter participate through U.C. Berkeley.

The goal of this project is to develop and apply models to improve the process of exposure assessment in two ways. First is to provide a more complete picture of how humans are exposed to a number of important pollutants. Second is to determine the level of precision that is feasible for quantifying human exposure to these pollutants. These efforts are being organized around two research components: (1) an indoor/outdoor model for total human exposure to particulate matter (PM); and (2) development and evaluation of source-to-dose models for persistent pollutants. These two components include a number of research areas.

December 2000

D. Bennett, T. McKone and M. Margni continued to work on a paper describing the use of "dose fraction" as a measure of exposure in regional multimedia models. Dose fraction, Df, is the fraction of chemical mass emitted into the environment that eventually passes into members of a population through inhalation, ingestion, or dermal exposure. To date, this concept has been primarily applied to pollutants whose route of exposure is inhalation. In this paper, we extend the use of Df to multimedia pollutants with multiple exposure pathways. We use a level III multimedia model to calculate Df for TCDD and compare the result to one calculated from measured levels of dioxin in the environment. We also calculate Df for emissions to air and surface water for 244 chemicals. This paper is being prepared for a special issue on Life Cycle Analysis and Comparative Risk Assessment in the journal *Risk Analysis*. In early December, T. McKone made an oral presentation on this work at the Society for Risk Analysis meeting in Washington DC.

Agnes Bodnar, D. Bennett, R. Maddalena, M. Margni and T. McKone continued to work on version 4 of CalTOX, which is scheduled for release in January 2001. The work on the dose fraction paper helped identify exposure pathway algorithms in CalTOX that needed to be updated. A working paper on the algorithm updates was drafted. The CalTOX manual was also revised and is scheduled to undergo review in January.

W. Riley, T. McKone, and W. Nazaroff finished another draft of the paper entitled "Indoor Particulate Matter of Outdoor Origin: The Importance of Size-Dependent Removal Mechanisms." In December, W. Riley added estimates of integrated PM2.5 and PM10 deposition loss rates and filter efficiencies for both urban and rural atmospheres. These estimates are helpful in cases where size-resolved ambient concentrations, deposition velocities, and filter efficiencies are unavailable.

W. Riley continued to work on the dermal uptake model for short contact times. In December, he received and became familiar with the Malathion rat data provided by the EPA Las Vegas group. We will use this data to test and calibrate our transient, finely resolved dermal diffusion model, with the ultimate goal of providing easy-to-use estimates of absorbed dose as a function of contact time.

M. Sohn and T. McKone submitted a "scope-of-work" document entitled *Reconstructing Exposure Scenarios Using Dose Biomarkers* to Jerry Blancato at EPA's National Exposure Research Laboratory in Las Vegas, NV. The goals of the work are: 1) to identify or develop a robust biomarker data interpretation algorithm for simultaneous (i) exposure-event reconstruction and (ii) pharmacokinetic-processes description; and 2) to apply the algorithm to an as-yet-to-be-determined biomarker data set. The application will assist exposure assessment researchers with their understanding of the data set and help to reveal how the quality and quantity of data improves pharmacokinetic system description. Our approach is to use simple physiologically-based pharmacokinetic models with Bayesian statistics to conduct a large-scale, integrated uncertainty analysis.

N. Klepeis worked on compiling the MIAQ4 model for indoor air quality under the GNU gcc free software tools. The program can now be compiled and run on a wide range of platforms including GNU/Linux, Unix, Windows 9X, Windows 2000, Mac OS X, OS/2, and others. The MIAQ4 program is an integral part of an upcoming paper on the particle emissions characterization of cigars and cigarettes. MIAQ4 has also been modified to facilitate the optimization of emissions and deposition parameters from observed time series data.

D. Bennett worked on model assessments to compare health impacts linked to choices of energy and cooking fuels in developing countries. Indoor and outdoor air quality are considered as measures of health impact for different mixes of fuel stocks. This work was reported in the paper entitled "Environmental Exposure Modeling For Low- and Middle- Income Countries," which was presented at the Society for Risk Analysis meeting in Washington DC.

A. Bodnar analyzed data collected previously on soil-air-leaf partitioning, reactions in plants, and soil-root-plant transfers. She compared these observations with the predictions of existing plant-uptake models. This analysis is ongoing, and preliminarily results are confounding. Bodnar is also collecting data on source characterization and PAH emissions to the San Francisco Bay Area air shed. These data are being used to relate the emissions of PAHs with potential inhalation and ingestion exposures to the Bay Area population.

D. Total Risk Integrated Methodology (TRIM) Project

TRIM.FaTE Project
Sponsor(s): U.S. EPA Office of Air Quality, Planning and Standards
Collaborator(s): Oak Ridge National Laboratory, University of Tennessee, ICF Consulting

Background
Randy Maddalena, Tom McKone, Deborah Bennett, and Agnes Bodnar are working on this project. The Total Risk Integrated Methodology (TRIM) is an EPA project to develop models and data for assessing the multimedia residual health and ecological risk from pollutants released to air sheds. The LBNL team is working on two components of the TRIM project: (1) testing, evaluation, and validation of the TRIM.FaTE module; and (2) development of the TRIM.Expo multimedia, multipathway exposure model.

December 2000
There was no activity to report for December.

E. Criteria for Evaluation and Development of Probability Density Functions for a Set of Human Exposure Factors

Exposure Factor Distributions
Sponsor(s): U.S. EPA Office of Emergency and Remedial Response
Collaborator(s): None

Background
Randy Maddalena, Tom McKone, and Agnes Bodnar are working on this project. The Office of Emergency and Remedial Response (OERR) plays a lead role in developing national guidance and planning future activities that support the EPA Superfund Program. The purpose of this project is to develop for OERR methods for scoring the quality, relevance, and reliability of probability density functions.

December 2000

R. Maddalena and T. McKone prepared a presentation on this project for the Society for Risk Analysis meeting in Washington DC. R. Maddalena wrapped up the research component of the project and shifted efforts to the preparation of the final report. The final report is being prepared in two parts - Part 1: Evaluation Criteria for Probability Density Functions used for Human Exposure Factors, and Part 2: Towards Development of Default Distribution in Probabilistic Risk Assessment. Part 1 provides a detailed description of the evaluation framework that we developed for use by risk managers charged with judging the quality of a Probabilistic Risk Assessment (PRA). This framework focuses on the seven critical attributes that influence the quality of the distribution from the reviewers' perspective rather than from the risk assessors' perspective. Part 2 presents three case studies that move towards development of

"default" distributions for use in PRA. The case studies include body weight (BW), exposure duration (ED) and drinking water ingestion (I_{water}) distributions. The case studies illustrate the development of simple yet relevant models that are readily applicable to different population compositions without the need for large amounts of new information. The BW case study introduces a method that we developed using age/gender categories and census data to construct relevant distributions. The ED case study uses the same approach as the BW case study but introduces a model of residence time for a specific housing stock. The I_{water} case study addresses the problem of using data from short-term surveys to construct distributions for PRA. We show how short-term survey data significantly inflates the variance in the distribution and therefore provides a poor approximation of variance across a specific population.

F. Inter-Individual Differences in Metabolism of Carcinogens as a Risk Factor for Breast Cancer
Sponsor(s): U.S. Department of the Army
Collaborator(s): None

Background
The purpose of this project, led by Regine Goth-Goldstein, is to test for possible genetic factors that contribute to breast cancer risk, such as inter-individual variation in the level of enzymes that activate or detoxify environmental carcinogens. Variation in the level and activity of these enzymes can be due to mutations in the DNA sequences of the genes coding for these enzymes (genetic polymorphism) or to modification of gene expression by genetic and environmental factors. We have focused on the cytochrome P450 enzymes CYP1A1 and CYP1B1, both involved in activation of polycyclic aromatic hydrocarbons (PAHs). We are investigating whether the level of expression of these genes in breast tissue represents a risk factor for breast cancer.

December 2000
When measuring the expression of *CYP1B1* in breast tissue from breast cancer cases and controls using our semi-quantitative reverse transcriptase (RT) PCR assay, we have found that *CYP1B1* is expressed at significantly higher levels in breast cancer cases than in controls. We have now compared *CYP1B1* expression in tumor tissue versus normal tissue for five patients to evaluate if higher *CYP1B1* levels are related to the disease process or play a causative role in the disease. The results were ambiguous. In one case, nontumor tissue had higher *CYP1B* expression than tumor tissue. For three individuals, expression was higher in tumor than nontumor tissue. In one individual, where two different tumors and two metastasis to the lymph node were available, *CYP1B* expression in nontumor tissue, one tumor, and one metastasis was comparable, but in one tumor and the other metastasis it was increased 3- and 9-fold, respectively. This might indicate that changes in *CYP1B1* expression are not part of the disease process, but rather a sign of the multiple, random changes occurring in tumor progression.

We have started to write a manuscript on *CYP1B* expression as a risk factor for breast cancer.

G. Measurement of Semi-Volatile Organics in Ambient Air

Sponsor(s): U.S. EPA, EPRI, University of Texas, Washington State University
Collaborator(s): U.S. EPA, EPRI, University of Texas, Washington State University, Environment Canada, University of Washington, U.C. Berkeley, U.C. Los Angeles, Desert Research Institute, Restek Corporation, URG Corporation

Background
The objective of this project, led by Lara Gundel, is the development, validation, and application of new measurement methods for the accurate determination of semi-volatile organic pollutants in ambient air. Such species partition between the gas and particle phases in ways that complicate measurement and apportionment efforts. LBNL is contributing to several multi-investigator studies whose overall goal is the characterization of carbonaceous particles across the U.S.

December 2000
IED staff collaborated with colleagues at the US EPA to prepare a report and journal articles on the results of recent validation studies for diffusion-based sampling methods for semi-volatile and particulate organic pollutants. Proof-of-principle experiments were conducted with a new compact combined size-selective inlet and denuder for personal sampling. A paired filter sampling strategy was deployed inside and outside of an instrumented residence in Fresno as a first step in assessing the contribution of semi-volatile organics to the large indoor sampling artifacts that have been observed in DOE-funded studies.

H. Other Efforts

December 2000
The Exposure and Risk Analysis Group held two group meetings.

1. On December 11, Ashok Deshpande from the Environment Agency of India gave a presentation on the use of fuzzy logic in setting water standards for the Ganges River.

2. On December 18, Manuele Margni gave a presentation summarizing his work on multimedia models and dose fraction. This work was completed during his five-month stay at LBNL.

The Exposure and Risk Analysis group launched a revised version of its web site available at eetd.lbl.gov/ied/ERA/.

D. Bennett, M. Margni, T. McKone, W. Nazaroff, and W. Riley from LBNL; John S. Evans from Harvard University; and Kirk Smith from UC Berkeley, the Dose Fraction Working Group, continued work on a manuscript that will define and illustrate the concept of "Dose Fraction."

Regine Goth-Goldstein worked on two grant proposals to study the health effects of 7*H*-benzo[*c*]fluorene (B[*c*]F). One study will examine the role of B[*c*]F in breast cancer, the other in collaboration with Lara Gundel will examine the role of B[*c*]F in tobacco-induced lung cancer.

OUTSIDE CONTACTS

December 2000

D. Bennett and T. McKone attended the Annual Meeting of the Society for Risk Analysis (SRA), December 3 - 6 in Washington DC. T. McKone helped organize the meeting and served as co-chair of a symposium entitled "Is there a common future for Comparative Risk Assessment and Life Cycle Assessment?"

At the SRA meeting, the following platform presentations were authored or co-authored by members of the Exposure and Risk Analysis group and funded collaborators:

1. "Pollutants without Borders: Tracking Cumulative Exposures to Persistent Pollutants," T.E. McKone, D.H. Bennett and R.L. Maddalena, LBNL.

2. "Evaluation of PDFs: Body Weight and Exposure Duration Case Studies at the Extremes," R.L. Maddalena and T.E. McKone, LBNL.

3. "Environmental Exposure Modeling For Low- and Middle- Income Countries," D.H. Bennett, LBNL.

INDOOR ENVIRONMENT DEPARTMENT

5. International Energy and Environmental Activities

A.J. Gadgil
510- 486-4651

A. UVWaterworks
Sponsor(s): DOE-EE
Collaborator(s): None

Background
The UVWaterworks system uses ultraviolet (UV) light to treat water contaminated with bacteria, viruses, and Cryptosporidium. The technology, developed at the Lawrence Berkeley National Laboratory, has been licensed to WaterHealth International (http://www.waterhealth.com). DOE has supported limited field trials of the technology in South Africa, as part of DOE's participation in the SA-US-BiNational Commission.

December 2000
In December 2000, we again began experiencing difficulties in obtaining regular reports of water quality testing at the two sites in South Africa (Greenock and Flint Farm) where UVW units are being tested. Earlier, in late November we had received reports of large number of heterotrophic counts in treated water. The counts were so high that we suspect mislabelling of samples. We hoped to sort this out in December, however, the reporting of test results was sporadic. We hope to be able to address this problem in January 2001.

B. Other Efforts

None.

INDOOR ENVIRONMENT DEPARTMENT

6. Program Support and Administration

W.J. Fisk
510-486-5910

December 2000

IED staff prepared written responses to the comments of the review panel assembled in November by the LBNL Director to review the Divisions buildings-related research. The comments of the review committee on IED's research were very positive.

The search committee established by the EETD completed interviews of prospective candidates for the permanent Head of IED.

7. STATUS OF FY2001 DELIVERABLES FOR DOE/OBT

Deliverable or Milestone	Due Date	Status
TASK 1. ENERGY PERFORMANCE OF BUILDINGS		
Completion of First Public Review of Standard 62.2	11/00	Completed
Preliminary Analysis of Air Leakage Database	1/01	Completed
Status report on Energy Efficiency Ventilation Demonstration Case Study	3/01	
Recommendations regarding future participation of the US in AIVC	5/01	
Second Public Review of Standard 62.2	7/01	
Technical paper on infiltration heat recovery	9/01	
TASK 3. VENTILATION AND IAQ CONTROL TECHNOLOGIES		
Submit paper on comparative assessment of particle air cleaning	11/00	Delayed
Submit journal paper on a new approach for measuring the concentrations of VOCs in vinyl flooring	12/00	Completed
Submit journal paper on validation of a single-layer model to predict emissions rates of VOCs from vinyl flooring	3/01	
Paper on literature review and product and practice survey for measurement and control of outside air supply by HVAC systems	7/01	
Conference paper on methodology for establishing health- and comfort-based criteria for VOC emissions from building materials	9/01	
Paper on task ventilation optimization studies	9/01	
TASK 4. HEALTH BUILDINGS AND PRODUCTIVITY RESEARCH		
Submit paper on IAQ, ventilation, and health in schools	10/00	Completed
Complete data collection in productivity field study	12/00	Completed
Article for ASHRAE Journal or equivalent on ventilation rates and health	6/01	
Paper on analyses of BASE Study data from 100 buildings	7/01	
Draft paper on productivity field study	8/01	
Expanded article on association of symptoms with high-efficiency filtration, temperature, and humidity is accepted for publication	9/01	
Submit journal article on HVAC and health	9/01	
TASK 5. ENERGY EFFICIENT FUME HOODS		
Technical paper on design development and test results of high-performance fume hood	6/01	
Article on high-performance fume hood for professional publication	12/01	
Task 6. IAQ Assessments of New Energy-Efficient Housing		
Submit journal paper on sources of formaldehyde and other VOCs in a new manufactured house	9/01	